

Effect of Electron Beam Irradiation on the Bacterial Load and Sensorial Quality of Sliced Cantaloupe

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ABSTRACT: Electron beam irradiated sliced cantaloupe was tested for 21 d of storage for total aerobic microbial counts, texture, color, and different sensorial parameters as a function of irradiation doses 0, 0.7, and 1.4 kGy and the wash treatments, 1 and 200 ppm chlorine applied to the melons before cutting. Irradiation resulted in a reduction in the total aerobic microbial counts with increasing doses. Melons washed only with water before cutting had total aerobic bacterial counts of 4.0, 2.0, and 0.8 log colony-forming units (CFU)/g on day 0 at irradiation doses of 0, 0.7, and 1.4 kGy, respectively. Across all doses of irradiation, counts were consistently lower for cantaloupe pieces obtained from melons that had been subjected to chlorine rinse in comparison with those washed with water without chlorine. Melons washed with chlorine before cutting had total aerobic bacterial counts of 2.7, 0.7, and 0.5 log CFU/g on day 0 at irradiation doses of 0, 0.7, and 1.4 kGy, respectively. Objective color analysis indicated no significant effect of irradiation on the color of cantaloupe. Texture measured as compression force was lower only for cantaloupe irradiated at 1.4 kGy. Irradiation did not affect descriptive attribute flavor and texture sensory attributes of cantaloupe pieces. Decontamination of whole cantaloupes before cutting using chlorine wash may be combined with low-dose irradiation for shelf-life extension of sliced cantaloupe.

Keywords: electron beam irradiation, aerobic plate count, cantaloupe, chlorine, sensory analysis

Introduction

The importance of fresh fruits and vegetables as a rich source of nutrients and their role in promoting good health has resulted in an increase in their demand over the past decade. Increased consumption of fresh produce resulted in a corresponding increase in the incidence of foodborne diseases. A variety of commodities such as cantaloupe, mangoes, tomatoes, oranges, berries, and parsley have been implicated in outbreaks of foodborne illnesses. *Salmonella* has been found to be 1 of the pathogens most frequently associated with cantaloupe leading to several outbreaks across the United States and Canada (Ries and others 1990; Beuchat 1996; Mohle-Boetani and others 1999).

In the United States, a large multi-state outbreak of *Salmonella* serotype Chester was traced to the consumption of cantaloupes in 1990. In another outbreak, more than 400 cases were reported from 23 states in the United States and 2 provinces in Canada. The causative agent of the illness in this outbreak was *Salmonella* serotype Poona linked to the consumption of contaminated cantaloupes produced in Texas (CDC 1991). Three multistate outbreaks of *Salmonella* Poona infections associated with eating cantaloupe imported from Mexico occurred in the spring of 2000, 2001, and 2002 (CDC 2002).

The convenience of consuming packaged fresh-cut fruits caused

these products to be a rapidly growing segment of the retail and foodservice industry. Alongside developments of new technologies for packaging fresh-cut produce arose challenges related to extending shelf life and ensuring their safety. One of the issues of concern is the contamination of tissue with bacteria from the surface during cutting. Transmission of pathogens to the interior of the cantaloupe is possible while cutting unwashed melons (Beuchat 1996). Cantaloupes have a relatively high pH (6.1 to 6.6) that, along with sugars and high water content, makes them an ideal substrate for the proliferation of bacteria that may be introduced at low numbers. This results in the need for efficient decontamination strategies for fruits followed by optimum storage conditions for ensuring safety and maximizing shelf life. This would include antimicrobial rinses (Ayhan and others 1998; Luna-Guzman and Barrett 2000; Sapers and others 2001; Barak and others 2003) and effective preservation technology to retard the natural changes of minimally processed fruits and vegetables during storage (Bai and others 2000; Lami-Kanra and others 2000).

Fresh fruits and vegetables are commonly packed in plastic film bags or containers overwrapped with films, which create a modified atmosphere with time. The material chosen for packages has an optimum permeability for gases, and storage at low temperature lowers the respiration rate of fruit. A low level of oxygen in the package may retard browning and spoilage and maintain fresh appearance of the fruit; however, it can also cause off-flavors (Cameron and Smyth 1997). A very low level of O₂ or a high level of CO₂ in the package may inhibit the growth of spoilage microorganisms but may allow or stimulate the growth of foodborne pathogens (Farber 1991).

Ionizing radiation has been studied for its effectiveness in eliminating pathogens from a variety of fruits and vegetables. Irradia-

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tion at high doses leads to a change in quality, especially texture, of most commodities. In this study, we propose that a combination of decontamination rinse before cutting followed by low-dose irradiation of the cut fruit would help overcome this quality change. We investigated the effectiveness of chlorine water rinses of cantaloupe and low-dose electron beam irradiation on the microbiological and sensory characteristics of sliced cantaloupe over 21 d of storage.

Materials and Methods

Package designing

A preliminary study was conducted to determine the optimum material for packaging sliced cantaloupe. Cantaloupe pieces were cut as described below and amounts of 100, 200, 250, and 300 g were packed in 2 types of 15 × 19-cm polyethylene bags with varying thickness of material. The 2 bags under consideration were Whirl-Pak™ and Ziploc bags. The bags were double-sealed and stored at 5 °C. At the end of 8 d, a gas sample was withdrawn from the bags using an airtight syringe and analyzed for percentage of oxygen using an oxygen analyzer (S-3A/I AEI Technologies Inc., Pittsburgh, Pa., U.S.A.) and carbon dioxide using an infrared gas analyzer (Horiba Model PIR-2000, Irvine, Calif., U.S.A.). The package and fruit weight combination that had the lowest oxygen permeation rate at the same time preventing anaerobic fermentation of the fruit was chosen for the irradiation and storage of cantaloupe pieces.

Fruit preparation and packaging.

Cantaloupes (*Cucumis melo* L var. *reticulatus*) were purchased from a major supplier. The fruit were unwashed and boxed in the field. All melons were washed in the laboratory with distilled water along with gentle scrubbing using a brush for 2 min, after which half of the fruits were further dipped in a solution with 200 ppm sodium hypochlorite for 3 min. Excess chlorine from the surface of melons was washed off with distilled water rinses before the melons were set to dry for 12 h at 21 °C. The fruits were then separated into 2 groups, depending on the wash treatment. Each cantaloupe was sliced and cored into 1-inch-dia cylindrical pieces using a stainless-steel corer. All materials used for cutting and handling were continually sanitized using 70% ethanol and flame to prevent cross-contamination. The cylindrical pieces of fresh-cut cantaloupe were packed in 15 × 19-cm polyethylene bags. Each bag contained 100 g of fruit and was double-sealed using an Impulse Heat Sealer (American Intl. Electric, Whittier, Calif., U.S.A.) to ensure hermetic conditions. The previously discussed package design was established after the preliminary experiment described earlier, which allowed determination of the optimum packaging film and the exact weight of fruit to be packed so that the gas permeation rate of the film balances the respiration rate of the fruit at 5 °C.

Irradiation treatment

Cantaloupe packets were placed in a single layer in cardboard boxes on a conveyor and exposed to either 0.7 or 1.4 kGy electron beam irradiation. The dose of 0.7 kGy corresponds to the highest reported D value for non-sporeforming pathogens according to Olson (1998) and higher dose of 1.4 kGy was also chosen in this study to investigate its effect on quality of cantaloupe at double-dose intensity. The irradiation treatment was carried out at the Natl. Center for Electron Beam Food Research at Texas A&M Univ. A non-irradiated set of packets served as the control. Upon irradiation, the zero day bags were immediately analyzed and the remaining bags, along with the control, were transferred to the cold room for storage

at 5 °C for up to 21 d. Periodically, packets were removed for microbiological, texture, and color analysis as well as sensory evaluation by a trained sensory panel.

Microbiological analysis

Aerobic plate count (APC) was carried out to determine the microbial load of the sample. At each sampling time, packets were opened aseptically using scissors flame sterilized after dipping in 70% ethanol. A 25-g sample was weighed out from each packet and placed into a stomacher bag with 0.1% peptone water. This mixture was pummeled in a Laboratory Blender (Stomacher 400, Seward, London, U.K.) at high speed for 2 min. Appropriate serial dilutions were made from this homogenate and inoculated on APC Petrifilm™ plates (3M, St. Paul, Minn., U.S.A.). These plates were incubated at 25 °C for 48 h and the developing red-colored colonies were reported as colony forming units (CFU). Colony counts were calculated as CFU/g and then converted into log value for statistical analysis.

Analysis of texture and color

Texture in the form of firmness was measured as the force (N) required for a puncture effect on the flat side of each melon cylinder. Three pieces per packet were analyzed on a Texture Analyzer (TA.XT2i, Texture Technologies Corp., Scarsdale, N.Y., U.S.A.) with a 25-kg load cell. A 5-mm-dia flat-headed stainless-steel cylindrical probe traveled 30% of the height of the cylinder at 1 mm/s and the first peak force value obtained during the test was recorded (Luna-Guzmán and others 1999). Objective color was determined by taking 3 pieces of fruit per packet and measuring the color using a Hunter colorimeter (Hunter Assoc, Reston, Va., U.S.A.; McGuire 1992). The L^* , a^* , and b^* color space values were recorded and hue and chroma values were calculated. Hue and chroma were calculated from a^* and b^* values using the following formulas:

$$\text{Hue} = \arctan \frac{b^*}{a^*}$$

$$\text{Chroma} = \left[(a^*)^2 + (b^*)^2 \right]^{1/2}$$

Sensory evaluation

The sensory analysis of cantaloupe was carried out by an expert, trained 5-member descriptive attribute sensory panel at the Sensory Testing Facility at Texas A&M Univ. Panelists were selected as described by the American Meat Science Assn. (1995) and Meilgaard and others (1999). Training and ballot development sessions were conducted to determine color, odor, flavor, basic tastes, and texture attributes of cantaloupe. Products for training represented cantaloupe from the treatments and storage times defined in the study. Terms from Civille and others (1996) and Meilgaard and others (1999) were used to assist in identifying attributes. For color, paint cards ranging from yellow to dark orange were obtained. A color reference card was developed so that 1 = light orange and 8 = dark orange. Color standards used were SW6888, SW 6889, SW 6890 and SW 6891 (Sherwin-Williams Co. Cleveland, Ohio, U.S.A.). Attributes were identified as fermented, earthy, soured, nutty, musty, and fruity odors and flavor aromatics, sweet, sour, and bitter basic tastes, and hardness and firmness textures. Descriptive attributes were evaluated on the 15-point Universal Spectrum™ scale in which 0 = none and 15 = extremely intense. After training, panelists evaluated 18 samples per day while seated in individual booths separated from the sample preparation area. Samples were identified with random 3-digit codes and served by treatment in

random order. Each sensory day, panelists conducted a warm-up sample from the control to standardize the panelists within a day. Panelists were given double-distilled deionized water, saltless saline crackers, and ricotta cheese to cleanse their palates between samples. Samples were served no less than 4 min apart to reduce halo effects and taste bud fatigue. Panelists were given 6 samples at a time with a 20-min break between each set. On each day of analysis, the samples were removed from the refrigerator at least 1 h before serving to allow them to equilibrate at room temperature (20 °C). The panelists were served the pieces of cantaloupe in transparent glass bowls covered with a concave glass lid. Panelists first slightly shook the container with the lid intact, moved the lid slightly, and evaluated cantaloupe odors. Then the panelists bit into a cantaloupe piece and evaluated flavor aromatics, basic tastes, and texture attributes.

Statistical analysis

Data recorded for each parameter tested in 3 trials were analyzed by analysis of variance using the analysis of variance (ANOVA) procedure of SAS (Statistical Analysis Systems Inst., Cary, N.C., U.S.A.). When ANOVA indicated a significant difference ($P < 0.05$), mean separation was carried out by the Duncan's multiple range test. Data for subjective sensory evaluation was analyzed by the Mixed Procedure of SAS and least square means were obtained. Least square means were separated when the effect was significant in the ANOVA table ($P < 0.05$). For sensory data, panelist and panelist by main effect interactions were tested. Since panelist by main effect interactions were not significant, these were pooled into the error term. Microbiological data were also analyzed by linear regression to establish the effect of different treatments on the bacterial counts over storage time.

Results and Discussion

Gas composition of the package

The gas composition of the package made using 2 different materials at the end of 8 d is shown in Figure 1. The material of Ziploc bags had a higher oxygen permeation rate, which resulted in

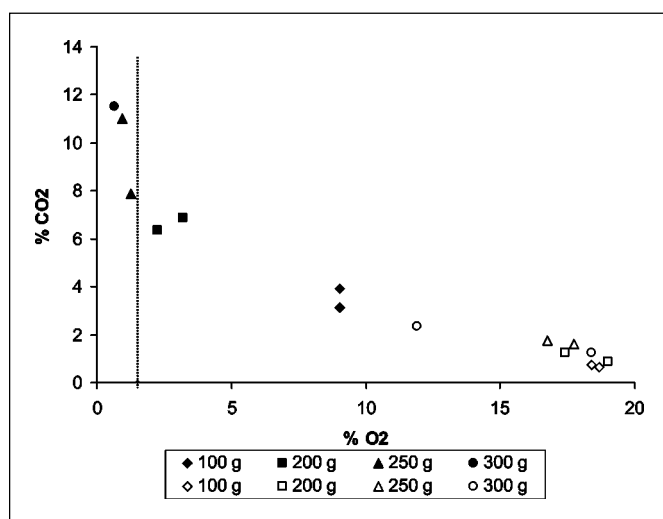


Figure 1—Gas composition of Whirl-Pak™ and Ziploc bags containing different amounts of sliced cantaloupe after storage at 5 °C for 8 d. Solid data points denote Whirl-Pak bags and hollow data points denote Ziploc bags. The dotted line marks the beginning of anaerobic fermentation of fruit with increasing sample weight in the packet.

higher oxygen levels in these packages (Figure 1). Bags containing fruit ≤ 300 g did not show anaerobic fermentation. On the other hand, Whirl-Pak™ bags were less permeable to oxygen (Figure 1). Thus lower oxygen levels could be achieved, depending on the amount of fruit in the bag. Bags containing ≤ 200 g of fruit did not show anaerobic fermentation. The oxygen level in Whirl-Pak bags containing 100 g cantaloupe was 9%, and the carbon dioxide level was 3%. Bags containing ≥ 250 g melon pieces showed a sharp rise in carbon dioxide level below the 1% oxygen level, indicating anaerobic fermentation of fruit. Whirl-Pak bags containing 100 g of cantaloupe pieces were chosen for the irradiation study.

Microbiological analysis

Electron beam irradiation reduced the total aerobic microbial counts of water-washed and chlorine-washed fruit during the irradiation process (day 0; Figure 2). For the water-washed melons, APCs for the nonirradiated fruit was 4.0 log CFU/g with a reduction in count by 2.0 log CFU/g at 0.7 kGy and 3.8 log CFU/g at 1.4 kGy. For the chlorine-washed melons, APCs for the nonirradiated fruit was 2.7 log CFU/g with a reduction in count by 2.0 log CFU/g at 0.7 kGy with APCs below the detection limit at 1.4 kGy. This indicates that the electron beam exposure resulted in significant reduction of microbial populations dependent on the dose intensity and wash treatment. On day 0, melons washed with chlorine were 1.3, 1.3, and 0.3 log CFU/g lower in APC than those washed only with water at doses of 0, 0.7, and 1.4 kGy, respectively. These results were consistent across the control and irradiation doses as well as throughout the 21-d storage period. The antimicrobial action of chlorine on the surface of the melons may have resulted in fewer bacteria contaminating the flesh. A similar observation has been reported by Ukuku and others (2002) with their work using *Listeria monocytogenes* inoculated on the surface of whole cantaloupe. They found that sanitization of whole cantaloupes with chlorine or hydrogen peroxide has the potential to reduce or eliminate the transfer of *L. monocytogenes* on melon surfaces to fresh-cut pieces during cutting. Our results show the effectiveness of combining decontamination wash with subsequent exposure to low doses of irradiation to achieve microbial reduction. In this study, the duration of storage of cantaloupe was also observed to have an effect on microbial counts. However, after 15 d of storage, there was no significant in-

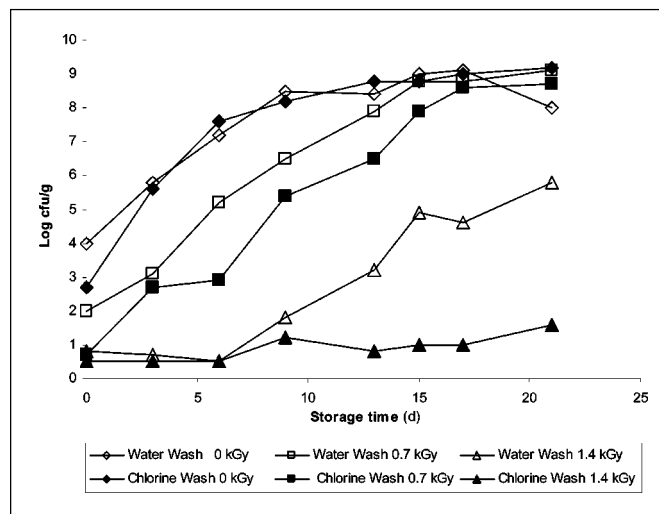


Figure 2—Aerobic plate count of sliced cantaloupe over 21 d of storage at 5 °C after electron beam irradiation

crease in bacterial counts for 0 and 0.7 kGy treated fruit. Storage at 5 °C is not conducive for growth of most organisms, typically pathogens such as *Salmonella* (Golden and others 1993); however, many mesophilic bacteria can grow at that temperature. Lamikanra and others (2000) reported an increase in total aerobic bacterial counts after an induction period of 5 d on minimally processed, cut cantaloupe stored at 4 °C. O'Connor-Shaw and others (1994) observed an increase in lactobacilli population from 3.3×10^4 to 3.6×10^6 CFU/g in fresh-cut cantaloupe stored at 4 °C. This highlights the need for appreciable reduction of bacterial load on cantaloupe during decontamination steps to prolong their proliferation to levels that would affect the fruit quality. These findings suggest that electron beam irradiation is a potentially viable decontamination tool and needs to be validated for its ability to eliminate pathogens associated with fresh-cut produce.

Objective texture and color analysis

Texture. The firmness of cantaloupe irradiated at 1.4 kGy was 4.94 N and was significantly lower than the control and 0.7 kGy. The firmness value for the control was 5.86 N and was not significantly different from 5.61 N for cantaloupe irradiated at 0.7 kGy (Table 1). This observation is consistent with the study by Hagenmaier (1998) of gamma-irradiated shredded carrots. There was no difference between texture of carrots treated at a low dose of 0.5 kGy and the nonirradiated control. However, other studies have reported softening of fruits after irradiation (Johnson and others 1965; Thomas 1986; Miller and others 1995). Yu and others (1995) reported that firmness of strawberries irradiated with electron beam at 0.5, 1.0, and 2.0 kGy were lower than control fruit. Johnson and others (1965) reported that gamma-irradiated strawberries became softer as irradiation dose increased from 1 kGy to 4 kGy. In our study, the type of wash treatment used for whole cantaloupes did not influence the firmness of the cut pieces (Table 1). There was a gradual and significant reduction in firmness values with storage time, which may be associated with senescence (Table 1). This tissue softening may be caused by partial depolymerization of cell wall polysaccharides, mainly cellulose and pectins (D'Amour and others 1993), and by damage to cell membranes (Voisine and others 1993), which leads to loss of intracellular water and cell turgescence. Additionally, radiation-induced texture change has been associated with changes in pectic substances (Kertesz et al 1964; Somogyi and Romani 1964; Howard and Buescher 1989). There was an interaction between irradiation dose and storage time for firmness (Figure 3). Firmness values for the control and 0.7 kGy treated fruits decreased following first-order kinetics at a similar rate with time, whereas firmness of 1.4 kGy irradiated fruit decreased at a lower rate (Figure 3). The data indicate that irradiation at doses as low as 0.7 kGy showed no difference on texture of cantaloupe compared with the nonirradiated control.

Color. Wash treatment had a significant effect on the lightness of cantaloupe pieces (Table 1), with chlorine-treated fruit having higher L^* values than fruit washed only with water. There was an effect of irradiation dose on L^* values with nonirradiated fruit having higher L^* values than 0.7 and 1.4 kGy irradiated fruit (Table 1). This observation was different from that observed by Yu and others (1995) for electron beam irradiated strawberries. They observed that Hunter L values increased with irradiation dose. Miller and others (1995) reported no change in color of 'Sharpblue' blueberries upon electron beam irradiation up to 1 kGy. Hue of 68.53 and Chroma of 27.67 were not affected by either washing or irradiation treatment, indicating that there was no visible color change in fruit after treatment (data not shown). In general, L^* , hue, or chroma values of the fruit did not change through time.

Table 1—Mean firmness values expressed in newton (N) and L^* color means, obtained from sliced cantaloupe as affected by wash treatment of whole melons and by dosage of electron beam irradiation of cut pieces^{a,b}

Effect	Firmness (N)	L^*
Wash		
P value ^c	0.22	0.003
Water ^d	5.55a	54.07a
Chlorine ^e	5.39a	55.58b
Dose		
P value ^c	< 0.0001	0.0007
0.0	5.86a	56.13a
0.7	5.61a	54.60b
1.4	4.94b	53.74b
Days		
P value ^c	< 0.001	0.54
0	6.01ab	54.63a
3	6.05a	55.00a
6	5.53bc	55.07a
9	5.48c	ND ^b
13	5.21cd	54.32a
15	5.09cd	55.22a
17	ND ^b	53.86a
21	4.93d	55.65a
Root Mean Square Error	0.73	2.77

^aMeans for factors within the column with the same letter are not significantly different ($P \geq 0.05$).

^bND = not determined.

^cP values from analysis of variance table.

^dManual wash consisting of dipping in distilled water, gently brushing with soft brush to remove soil. Each melon was brushed for 2 min.

^eManual wash followed by dipping and rotating for 3 min in distilled water added with 200 ppm sodium hypochlorite then rinsing with distilled water to remove excess chlorine.

Sensory evaluation. The least squares mean for each organoleptic parameter analyzed by the 5-member trained sensory panel are included in Table 2, 3, and 4. Irradiation dose and wash treatment did not affect sensory attributes, except sour basic taste. As irradiation dose increased, sour basic taste slightly decreased and was barely detectable for all treatments. The type of wash treatment had no influence on sensory attributes of cantaloupe. However, some sensory attributes were affected by storage time. This may be due to variation in maturity levels of certain melons and also the senescence of fruit with time. There was an interaction ($P = 0.01$)

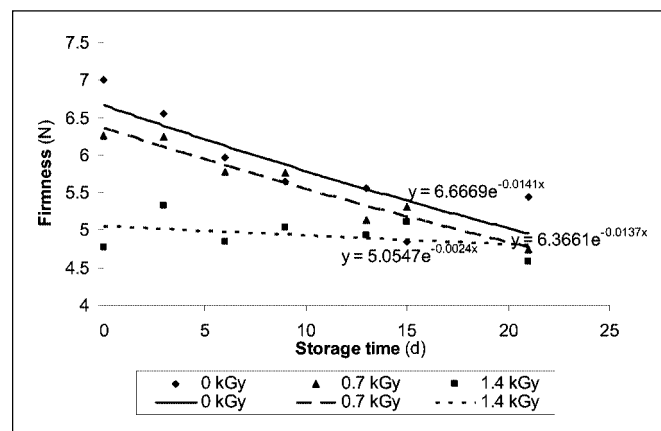


Figure 3—Mean cantaloupe firmness values (N) as affected by interaction between storage days and irradiation dose as obtained using a texture analyzer

Table 2—Least square means for different subjective sensorial odor attributes^a of sliced cantaloupe as affected by wash treatment of whole melons and by dosage of electron beam irradiation of cut pieces

Effect	Odor				
	Cantaloupe	Fermented	Earthy	Soured	Fruity
Wash	0.63 ^b	0.49	0.90	0.26	0.05
Water ^c	6.1	0.7	0.4	0.1	1.8
Chlorine ^d	6.0	0.7	0.4	0.1	1.7
Dose	0.93 ^b	0.61	0.98	0.07	0.78
0.0	6.0	0.8	0.4	0.1	1.7
0.7	6.0	0.7	0.4	0.1	1.8
1.4	6.1	0.7	0.4	0.1	1.7
Days	0.0001 ^b	0.0001	0.0035	0.0001	0.0001
0	5.3	0.5	0.4	0.0	1.9
3	5.4	0.1	0.1	0.0	2.3
6	6.6	0.3	0.6	0.0	2.1
9	6.9	0.8	0.5	0.0	1.8
13	5.8	1.0	0.5	0.1	1.4
15	6.4	0.9	0.3	0.1	1.7
17	6.4	0.9	0.5	0.4	1.7
21	5.6	1.2	0.5	0.4	1.2
Root mean square error	1.83	0.94	0.70	0.47	1.03

^aAttributes are based upon universal scales from 0 (no detection of the attribute) to 15 (highest intensity for the attribute).
^bP values from analysis of variance table ($P < 0.05$).
^cManual wash consisting of dipping in distilled water, gently brushing with soft brush to remove soil. Each melon was brushed for 2 min.
^dManual wash followed by dipping and rotating for 3 min in distilled water added with 200 ppm sodium hypochlorite then rinsing with distilled water to remove excess chlorine.

Table 3—Least square means for different subjective sensorial aroma attributes^a of sliced cantaloupe as affected by wash treatment of whole melons and by dosage of electron beam irradiation of cut pieces

Effect	Aroma				
	Cantaloupe	Fermented	Earthy	Soured	Fruity
Wash	0.44 ^b	0.30	0.50	0.74	0.53
Water ^c	6.9	1.0	1.0	0.3	2.5
Chlorine ^d	6.8	0.9	1.0	0.3	2.4
Dose	0.11 ^b	0.16	0.07	0.11	0.15
0.0	6.6	1.0	1.1	0.4	2.3
0.7	7.0	0.9	0.9	0.2	2.5
1.4	7.0	1.0	1.0	0.3	2.5
Days	0.0001 ^b	0.0001	0.0001	0.0001	0.0001
0	6.4	0.7	0.9	0.1	2.5
3	7.0	0.3	0.9	0.1	2.9
6	7.9	0.8	1.7	0.1	3.1
9	7.7	1.3	0.9	0.2	2.4
13	6.6	1.3	0.9	0.2	2.4
15	6.5	1.1	0.8	0.5	2.2
17	6.7	1.0	0.9	0.7	2.3
21	6.0	1.3	0.9	0.7	1.7
Root mean square error	2.1	1.07	0.89	0.6	1.27

^aAttributes are based upon universal scales from 0 (no detection of the attribute) to 15 (highest intensity for the attribute).
^bP values from analysis of variance table ($P < 0.05$).
^cManual wash consisting of dipping in distilled water, gently brushing with soft brush to remove soil. Each melon was brushed for 2 min.
^dManual wash followed by dipping and rotating for 3 min in distilled water added with 200 ppm sodium hypochlorite then rinsing with distilled water to remove excess chlorine.

effect of irradiation dose and storage days on sour aroma (Figure 4). With increased storage in control cantaloupes, sour basic taste increased; however with storage, sour basic taste increased at a slower rate in irradiated cantaloupes. There was also an interaction ($P = 0.04$) between dose and storage time on fermented flavor aromatic (Figure 5). On day 0, cantaloupe treated with 1.4 kGy had higher fermented flavor aromatics than nonirradiated control or 0.7 kGy treatment. With increased storage, fermented aromatic would expectantly increase. This increase was observed for control sam-

ples. Interestingly, fruit treated with 0.7 kGy did not increase in fermented aromatic as rapidly with storage as the control. This indicates that low doses of irradiation may have prevented fermentation of fruit during storage. Cantaloupe treated with 1.4 kGy did not increase in fermented aromatic with storage, even though they were initially higher at day 0. This indicates that when fruit were treated with 1.4 kGy, some fermentative processes were induced but at a low level. With storage, however, these fermentative processes did not continue. Sourness and fermented aroma is most

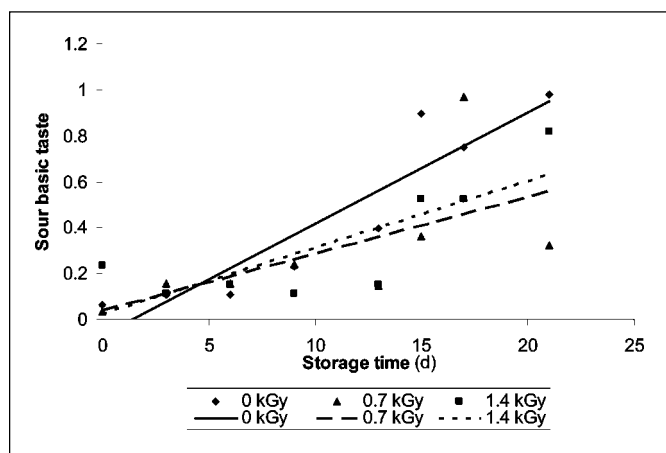


Figure 4—Least square means of sour basic taste due to the interaction between storage days and irradiation dose as observed by subjective sensory analysis of irradiated cantaloupe

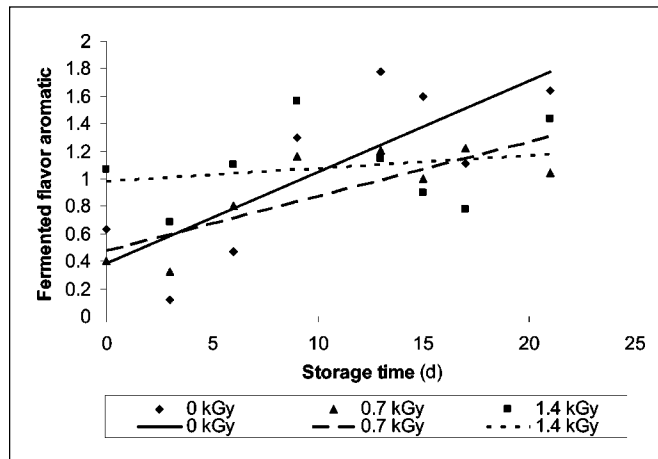


Figure 5—Least square means of fermented flavor aromatic due to the interaction between storage days and irradiation dose as observed by subjective sensory analysis of irradiated cantaloupe

Table 4—Least square means for different subjective color, taste, and texture attributes^a of sliced cantaloupe as affected by wash treatment of whole melons and by dosage of electron beam irradiation of cut pieces

Effect	Color	Texture			Basic taste		
		Slippery	Hardness	Juiciness	Sweet	Sour	Bitter
Wash	0.41 ^b	0.40	0.67	0.29	0.25	0.55	0.22
Water ^c	1.9	0.22	4.9	8.6	3.0	0.7	0.9
Chlorine ^d	1.8	0.2	4.8	8.7	2.8	0.7	0.8
Dose	0.98 ^b	0.12	0.43	0.49	0.14	0.02	0.33
0.0	1.8	0.2	4.9	8.6	2.8	0.9x	0.9
0.7	1.9	0.2	4.9	8.6	3.0	0.6y	0.8
1.4	1.8	0.2	4.8	8.8	3.0	0.7y	0.8
Days	0.0001 ^b	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
0	1.6	0.1	6.1	6.8	4.6	0.2	1.0
3	1.6	0.0	5.4	9.2	3.2	0.7	1.3
6	1.9	0.0	5.0	9.0	3.3	0.7	1.2
9	1.9	0.0	5.1	10.1	2.7	0.5	0.4
13	1.9	0.1	4.7	9.1	2.6	0.6	0.6
15	1.8	0.3	4.3	6.1	2.5	0.7	0.7
17	2.0	0.3	4.0	9.1	2.2	1.0	0.8
21	2.0	0.4	4.4	9.8	2.0	1.0	0.7
Root Mean Square Error	0.49	0.37	1.27	1.86	1.28	0.86	1.06

^aAttributes are based upon universal scales from 0 (no detection of the attribute) to 15 (highest intensity for the attribute). Color attribute is based on a 1 to 4 scale derived from standard chart with 4 colors with the points denoting the standard colors 1 = SW 6888 Pizzaz Peach, 2 = SW 6889 Stirling Orange, 3 = SW 6890 Osage Orange, and 4 = SW 6891 Mandarin. The values between 2 whole numbers indicate an intermediate shade.

^bP values from analysis of variance table ($P < 0.05$).

^cManual wash consisting of dipping in distilled water, gently brushing with soft brush to remove soil. Each melon was brushed for 2 min.

^dManual wash followed by dipping and rotating for 3 min in distilled water added with 200 ppm sodium hypochlorite then rinsing with distilled water to remove excess chlorine.

x,y = LS Means for attributes with the same letter are not significantly different ($P \geq 0.05$).

significantly caused by a higher level of microbial load on the non-irradiated control than the irradiated samples, resulting in greater fermentation of sugars into acid. As in objective analysis, subjective color and hardness did not appear to be significantly affected by irradiation or wash treatment. The texture analyzer used in objective texture analysis appeared to be sensitive to minute changes in firmness of cantaloupe, to an extent not perceivable to the sensory panel. As a result, although the instrument indicated difference in texture, the panel was unable to find any difference in hardness due to irradiation. Further research needs to be done to estimate the role of nonbacterial agents in the sensory quality of irradiated cantaloupe.

Conclusions

A combination of chlorine decontamination wash and low-dose electron beam irradiation can be an excellent tool for ensuring the reduction of spoilage organisms and extension of shelf life of sliced cantaloupe. Our results have clearly demonstrated the effectiveness of electron-beam irradiation in reducing the aerobic microbial load of fruit. Further work needs to be carried out to study the effect of irradiation on survival and proliferation of specific pathogens such as *Salmonella* associated with cantaloupe. The sensory data indicated that the color and texture of melons was not affected appreciably at 0.7 kGy. Also, no major off-flavors were detected other than the low level of sour taste and fermented aroma due to microbial growth in the control and to a small extent in the low-dose sample. Thus, with the use of chlorine decontamination, irradiation, and modified atmosphere packaging, the shelf life of fresh-cut cantaloupe was successfully extended to more than 10 d. The proposed combined technology for shelf life extension may have the potential to be applied to various other produce commodities to address quality and shelf life issues faced by the fresh-cut produce industry.

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